(F)

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 148 347 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: 01.04.87

(51) Int. Cl.[4]: H 02 P 6/02

(21) Application number: 84113102.2

(22) Date of filing: 01.05.81

(60) Publication number of the earlier application in accordance with Art. 76 EPC: 0 040 484

(54) Brushless D.C. Motors.

(30) Priority: 15.05.80 US 150202

(43) Date of publication of application: 17.07.85 Bulletin 85/29

(45) Publication of the grant of the patent: 01.04.87 Bulletin 87/14

(84) Designated Contracting States: DE FR GB IT NL

(56) References cited:
GB-A-1 245 195
GB-A-1 282 644

(73) Proprietor: ROTRON INCORPORATED
7 Hasbrouck Lane
Woodstock New York 12498 (US)

(72) Inventor: McDaniel, Wharton
33 Lower Byrdcliff Road
Woodstock New York 12498 (US)
Inventor: Brown, Fred A.
414 Zena Road
Woodstock New York 12498 (US)
Inventor: Thompson, Donald
R.D.1, Box 30
Kingston New York 12401 (US)

(74) Representative: Ellis, Edward Lovell et al
MEWBURN ELLIS & CO. 2/3 Cursitor Street
London EC4A 1BQ (GB)

Courier Press, Leamington Spa, England.

EP 0 148 347 B1

Description

The present invention relates to improvements in brushless D.C. motors and, more particularly, to such motors employing permanent magnet rotors and commutation circuits controlled by Hall effect elements.

Conventional D.C. motors, employing segmented commutators and brushes to achieve the polarity switching necessary for rotation, present certain obvious shortcomings. The wear on brushes and commutator segments necessitates periodic maintenance and/or replacement and the sparking occurring between the brushes and commutator segments produces undesirable radio disturbances. Moreover, the sparking presents a hazard where the motor is exposed to inflammable or explosive gases.

To avoid the disadvantages of mechanical commutation, a number of commutatorless systems for D.C. motors have been devised over the years. Basically, these systems employ some means for detecting or responding to rotation of the rotor to switch currents through the stator windings, so that the polarity of the latter are periodically reversed to maintain rotation. With the advent of solid state technology, it has been possible to reduce the physical size of the required circuitry such that it may be incorporated in the motor without any appreciable increase in overall size of the structure.

In one commercial form of brushless D.C. motor, a permanent magnet rotor is used and the rotation of the magnets is sensed by Hall effect elements. A Hall effect element, or Hall cell, is a low-power semi-conductor device, current flow through which can be altered by magnetic flux to produce a voltage output across a pair of output electrodes. The greater the magnetic flux density to which it is exposed, the greater the voltage output developed.

United States Patent Specification No. 3,631,272 discloses a D.C. electric motor having a groove formed perpendicular to the rotating direction of the rotor at the centre of the peripheral surface of one or more poles of the stator. A plurality of Hall elements are arranged at the centre of a substrate which is inserted into the groove.

United States Patent Specification No. 3,809,935 discloses a D.C. motor of the type commutated by Hall generators and solid state switching elements. It comprises a stack of parts connected together to an end of the motor through which its field winding conductors extend, and including a mounting for the Hall generators.

In these known motors employing Hall effect devices, the Hall effect devices are generally exposed to the magnetic fields generated by the permanent magnet rotor and the stator poles and complex circuitry is provided to sense the potential output of the Hall devices and generate the driving currents for the stator windings. Because of the normal response of Hall effect devices, these known motors require sophisticated mechanical adjustments to the rotor end/or stator structure to insure constant speed rotation of the rotor. These modifications may take the form of additional ferromagnetic members on the stator structure for the purpose of interacting with the rotor magnets to provide increments of torque in the gaps between energization of the stator windings. In another form, the air gap between the stator and rotor gradually increases and then decreases across each stator pole face for the purpose of storing and then releasing magnetic energy, to supply torque between periods of energization of the stator coils.

In another known system, complex mounting arrangements for the Hall effect devices are necessary to expose them to the magnetic flux from both the rotor magnets and the stator poles so that they counter each other and reduce voltage peaks through the driving transistors for the motor coils, thereby smoothing operation of the motor.

Another problem inherent in known D.C. brushless motors is difficulty in starting rotation of the permanent magnetic rotor, since the rotor tends to seek a rest position at the lowest reluctance point when the motor is shut off.

According to the present invention there is provided the combination of a brushless D.C. motor and a commutation circuit; the motor having at least one stator winding and a permanent magnet rotor; the semiconductor commutation circuit means for switching current in the at least one winding of the stator in dependence on the angular position of the rotor and to change the angular position of the magnetic field of the stator; the rotor carrying at least one permanent magnet having at least one pole proximate the stator, extending arcuately through a first angle and operative to impart rotary motion of the rotor upon commutated energization of the stator winding; the commutation circuit including switching means having a first state for conducting current through the winding in one direction and a second state terminating conduction of current through the winding in that direction, and Hall effect sensing means for detecting the angular position of the rotor to control commutation; characterized in that the Hall effect sensing means includes at least two Hall effect devices for changing output states in response to a magnetic field and effectively arcuately spaced apart by a second angle, each Hall device being coupled in control relation with the same switching means to cause that switching means to assume one of its said states when the first of the Hall devices is effectively proximate the rotor permanent magnet pole, maintaining the switching means in said one of its said states when either or both Hall devices are effectively proximate said magnet pole and returning the switching means to the other of its said states when the second Hall device effectively leaves the influence of the magnet pole, whereby the commutation arc of the permanent magnet is ax-

tended beyond the first angle of its arcuate spacing by the Hall devices.

The present invention will now be described in greater detail by way of example with reference to the accompanying drawings, wherein:—

Figure 1 is a partial cross-sectional view through a preferred form of brushless D.C. motor showing the mechanical arrangement thereof;

Figure 2 is a simplified vertical section through the motor, taken along the line 2—2 of Figure 1;

Figure 3 is another vertical section of the motor, taken along the line 3—3 of Figure 1, particularly showing the orientation of the Hall switches;

Figure 4 is an illustration of a commercially available Hall switch for use with the motor shown in Figure 1;

Figure 5 is a schematic circuit diagram of the commutating circuit in accordance with the present invention; and

Figure 6 is a series of waveforms for explaining the operation of the circuit shown in Figure 5.

The brushless D.C. motor shown in the drawings will be described in connection with a typical application, such as a fan. Such a fan is indicated at 10 in Figure 1, which is a cross-sectional view through the unit. Typically, a fan would comprise a spider or support plate 12 from which a series of outwardly extending struts 16 carry a venturi 14 which defines an air passage. The rotor assembly is indicated generally by the reference numeral 20 and the stator assembly by the reference numeral 30. Fans of this configuration are commonly known as tubeaxial fans.

A series of blades 26 extend radially from a hub 24 mounted on the rotor 20 of the motor. The hub 24 is fastened by screws 25 to a rotor frame 22.

The spider 12 is generally circular in shape and includes an axial bore at its centre defined by a tubular inward extension 12*a*. Extending through the bore of the tubular extension 12*a* is an arbor 32 which carries stator laminations 40.

Similarly, the rotor frame 22 is circular in shape and carries a shaft 28 which extends inwardly of the frame along the motor axis. As will be seen in Figure 1, with the stator and rotor assemblies combined to form the completed motor, the shaft 28 extends within the arbor 32, bearings 34 being provided to journal the shaft within the arbor. The arbor 32 is closed by a cap 36 which prevents leakage of the bearing lubricant and protects the motor against dust and dirt. Although a conventional spring-loaded ball bearing arrangement is illustrated in the drawing, it will be understood that other appropriate types of bearings may be used.

Extending through slots 41 in the stator laminations 40 (see Figure 2) are stator windings 42, the headspool portions of which are illustrated on either side of the laminations 40 in Figure 1. Insulating end caps 44 and 45 surround and protect the headspool portions of the stator windings 42 against abrasion and damage.

The stator assembly 30 so far described is of the snap-together construction as shown for example in the specification of U.S. Patent No. 3,919,572.

As is shown in the above referred to Patent Specification, and as illustrated in Figure 1 of the present specification the stator 30, including the arbor 32 with a radial flange 31 at its left end and the annular detent groove 33 near its right end, annular leaf spring 38, and insulating end caps 44 and 45, is assembled by first slipping the leaf spring 38 over the arbor, followed by the spider 12, intermediate elements 60 and 64 (to be described later), the end cap 45, the stator stack 40 with its headspool portions and, finally, the end cap 44 which has locking fingers forming its interior diameter. The dimensions of the foregoing elements and the location of the annular detent groove 33 on the arbor are such that when all these elements are pressed towards the flange 31 at the left hand end of the arbor, the locking fingers will engage the detent groove 33 on the arbor and hold the assembly firmly together.

The member 60 is a disc-like printed circuit board containing the components of the electronic circuit illustrated in Figure 5 and shown schematically at 62. The member 64 is an electrically insulating, thermally conducting layer which protects the circuitry on the board 60 and the elements from contact with conducting members of the stator assembly 30 while at the same time allowing heat to be conducted to the spider 12. The latter is made of aluminium or other highly thermally conductive material to act as a heat sink. A spacer ring 61 which may be integral with the spider 12 maintains the proper spacing of the circuit board 60 when the stator is assembled as above described. Power leads are coupled from a suitable connector on the spider through a hollow strut 16 to the printed circuit board 60, in known fashion.

The rotor assembly includes an axially extending tubular member 52 which is supported in cantilever fashion from the periphery of the rotor frame 22. The member 52 is formed of material having good magnetic properties, such as cold rolled steel while the rotor frame 22 is of non-magnetic material, such as aluminium.

The member 52, referred to as the rotor back iron, carries on its interior surface a series of elongated, curved permanent magnets 50, arranged around the stator laminations, as can be seen in Figure 2. The magnets may be formed of any suitable material, although ceramic magnets are preferred.

As will be evident from Figure 1, the axial length of the magnets 50 is substantially greater than the axial length of the stator stack 40, enabling proper orientation of the Hall switches 70, as will be described hereinafter. The natural tendency of the rotor magnets to centre themselves axially with respect to the stator stack is accommodated in the motor design illustrated to minimize bearing stress.

Referring now to Figure 2, which shows the shape of the stator laminations 40, it will be seen that the magnets 50 comprise two pairs of segmented elements 50*a* and 50*b*, arranged within

the tubular member 52. The magnets 50*a* and 50*b* each extend over somewhat less than 180 degrees of angular distance, e.g. 150°, leaving gaps between the two magnet segments. As indicated in Figure 2, the magnet pair 50*a* is magnetized such that its inner surface is its north pole and its outer surface its south pole, whilst the magnet pair 50*b* is magnetized in the reverse manner.

The stator laminations 40 are of a generally conventional type, having winding slots 41 provided therein to accommodate the stator windings, shown diagrammatically as 42*a* and 42*b*. Although shown as two separate windings in Figure 2 and in the circuit of Figure 5, the windings 42*a* and 42*b* may, in fact, be a single centre-tapped winding.

The stator slots 41 are closed at their peripheral openings by magnetic bridges 46 and 47 which complete the magnetic circuit of the stator. As will be explained hereinafter, the bridge member 46 is made longer than the stack to facilitate proper registration of the motor elements during assembly.

As shown in Figure 2, each of the laminations 40 is formed with steps 43*a* and 43*b* extending about one quarter of the distance along the respective pole faces 41*a* and 41*b*. These steps, which are about 0.228 to 0.254 m.m. in depth, are formed at the trailing edge of each pole face (with the direction of rotation of the rotor being in the clockwise direction as seen in Figure 2). In the assembled stack 40, each of the two pole faces will have a step, or reduced diameter portion, extending along its length at its trailing edge.

Since the step presents an air gap of increased reluctance as compared to the remainder of the pole face, the magnets 50*a* and 50*b* will centre themselves around the remainder of the pole face, i.e., the low reluctance portion of the air gap, when the motor is not energized. As will be explained more fully hereinafter, the angular displacement of the magnets with respect to the stator pole faces resulting from the step insures proper starting and direction of rotation of the motor.

Also shown in Figure 2 are the positions of two Hall effect switches 70 in the relation to the stator poles and the rotor magnets in de-energizxed condition of the motor. One of the Hall switches is located substantially aligned with the opening in one of the stator slots while the other switch is displaced about 30 degrees in an anti-clockwise direction from the first switch, while both are exposed to the magnetic field from the rotor magnets 50*a*. The precise angular position of the Hall switches can be varied somewhat to optimize motor performance.

Figure 3 shows the face of the printed circuit board 60 from the same direction as the structure in Figure 2. The Hall switches 70, the physical shape of which is illustrated in Figure 4, are mounted with the pins 72 inserted into suitable sockets provided in the panels 60 so that the switch extends perpendicularly from the face of the panel. To allow the switches 70 to extend into the space between the magnets 50 and the stator headspool portions 42 (see Figure 1) the end cap 45 is notched as shown. To effect proper alignment of the stator assembly with respect to the Hall switches, and thus with the rotor in the de-energized condition, an opening is provided in the printed circuit panel opposite the Hall switches, to accommodate an extended portion of the bridge member 46 which closes the stator slot on the associated side of the stator. Thus, properly aligned assembly of the stator stack may be accomplished simply by slipping it over the arbor 32 and rotating it until the bridge member 46 engages the corresponding opening in the circuit panel 60. This key makes improper mounting of the stator stack on the arbor 32 impossible.

Turning back now to Figure 2, it will be seen that with the rotor initially in the de-energized position shown, if poles 41*a* and 41*b* are magnetized with the proper polarities, magnets 50*a* will be attracted by the pole 41*b* and repelled by the pole 41*a* and magnets 50*b* attracted and repelled by the poles 41*a* and 41*b* respectively. This initial alignment starts the rotor structure rotating in a clockwise direction. If, as the rotor magnets reach their low reluctance position adjacent the opposite pole faces, the polarities of the poles are then switched, the movement of the rotor magnets will continue. Thereafter, alternate switching of the stator polarities will maintain rotation of the motor in that direction. The switching operation is achieved by the circuit shown in Figure 5, the components of which are mounted on the circuit board 60.

A commercially available Hall switch is shown in Figure 4. The Hall element itself is centered with respect to the broad face of the package and is responsive to a predetermined magnetic field polarity. Thus, the Hall switches 70 must be oriented in a particular manner with respect to the energizing magnetic field to produce the binary or digital voltage output required. In the present application, as seen in Figure 1, the Hall switches 70 are mounted adjacent the interior wall of the magnets. Since the rotor magnets 50*a* are magnetized oppositely from the magnets 50*b*, the Hall switches 70 will be activated only by one of the rotor magnet pairs. In the chosen type of switch, the Hall element is most responsive to flux from a south magnetic pole directed to the front face of the unit.

Figure 5 is a schematic circuit diagram of the commutating circuit. It will be understood that the components and conductors illustrated in Figure 5 are mounted on the printed circuit board 60 in the usual manner, discrete components such as transistors, resistors, etc. being designated generally by the numeral 62 in Figure 1.

D.C. power is applied between positive terminal 100 and earth or negative terminal 101 to supply both the stator coils and the commutating circuit. A diode 102 couples the input power to the common terminal of stator coils 42a and 42*b* whilst a diode 104 couples power to a voltage dividing and regulating circuits for powering the commutating circuit.

The voltage dividing and regulating circuit in-

cludes a resistor 106 and a zener diode 108 whose zener breakdown voltage is selected to be about 9 volts. The resistor 106, together with a transistor Q1, functions as a variable resistor and serves to maintain 9 volt D.C. at the emitter electrode of the transistor Q1 over a range of differing D.C. input voltages V+. The stator windings may be designed for a specific applied voltage, for example, 12, 24 or 48 volts, depending upon required characteristics, whilst in each case, the commutating circuit elements would require the same 9 volt level. It will be appreciated that the circuit panel 60 and its components need not be changed for any available input voltage extending up to 56 volts because the voltage division and regulating circuit consisting of the transistor Q1, the resistor 106 and the zener diode 108 provides the proper voltage level for the control circuit regardless of the voltage applied to the stator windings.

The Hall effect switches 70 are connected in parallel between the emitter electrode of the transistor Q1 and earch with their output terminals connected by a resistor 110 to the 9 volt power supply at the emitter electrode of the transistor Q1. Since, as described above, the output of the digital switch is in binary form, i.e., at some finite positive voltage or at earth, it will be seen that if the output of either or both of the switches are at the zero voltage level (the logical "0"), the voltage at their junction will be at the zero level. Only when both of the switches are at the positive voltage level (the logical "1") will the voltage at their junction be at the positive level. In the case of the chosen digital switch, the output of the unit will normally be at the logical "1", i.e., positive voltage, and will switch to the logical "0" (zero voltage) when the magnetic flux density to which it is exposed exceeds a predetermined threshold level.

With both of the Hall switches 70 providing a logical "1" output, positive potentials are applied to the base electrodes of transistors Q2 and Q4 through the resistors 114, 120, rendering both of these transistors conductive. conduction of the transistor Q4 permits current flow through the coil 42*b*, thereby energizing the corresponding stator pole. Conduction of the transistor Q2 maintains transistor Q3 non-conductive, thereby preventing current flow through stator coil 42*a*.

When either or both Hall switches 70 are subjected to appropriate polarity and value of magnetic flux density, the output drops to the logical "0" state, turning off the transistors Q2 and Q4. As the transistor Q2 turns off, its collector voltage rises, turning on the transistor Q3 to provide current flow through the stator coil 42*a*. The turn-off of the transistor Q4 terminates current flow through stator coil 42*b*. It will be seen then that alternate energization and de-energization off the Hall switches 70 by the magnets of the permanent magnet rotor will switch current flow between the stator coils 42*a* and 42*b*, thereby alternately mangetizing the stator poles with opposite polarity. A resistance-capacitance network, 116, 118 connected to the base electrode of the transistor Q3 and a similar network 120, 122 connected to the base electrode of the transistor Q4 prevent the respective transistors from turning on and off too rapidly, thereby reducing voltage and current transients to minimise radio frequency interference and power consumption of the circuit.

The waveforms of Figure 6 help to explain the operation of the circuit of Figure 5. The waveform A appears at the common output terminal of the Hall switches 70, the +9 volt level representing the logical "1" condition. The sloped portion at the leading edge of each pulse represents the effect of the resistance-capacitance network at the base electrode of the transistor Q4.

The waveform B illustrates the current flow through the coil 42*b* when the transistor Q4 is rendered conductive and waveform C the current flow through the stator coil 42*a*. The small current pulse appearing at the termination of each major current pulse represents the current flow produced by the inductive effect of the coil when applied current ceases. The diode 102 prevents switching transients from the stator coils from reaching the power supply and the diodes 102 and 104 protect against accidental reverse connection of the power supply.

Starting and rotation of the motor proceeds as follows. With no power supplied, the rotor of the motor would align itself, for example, in the de-energized position shown in Figure 2. In this position, the Hall elements of the switches 70 are not affected, since the direction of the fringe flux from the magnet 50*a* is opposite to the response characteristic of the element. Thus the Hall switches are not energized and their output (at point A, Figure 5) is at the logical "1" level, turning on the transistor Q4 and energizing the stator coil 42*b*. Stator pole face 41*b* becomes a "south" pole and pole face 41*a* a "north" pole with coil 42*b* energized, tending to draw magnets 50*a* and 50*b* towards pole faces 41*b* and 41*a*, respectively, in a clockwise direction and, simultaneously, repelling magnets 50*a* and 50*b* from pole faces 41*a* and 41*b*, respectively.

As magnet 50*a* rotates past the Hall switches 70, the output of the latter remain in the "1" state and that condition will prevail until the magnet 50*b* rotates to overlap the closest of the Hall switches.

At that instant, the fringe flux orientation from the magnet 50*b* is in the proper direction to activate one of the Hall switches 70, thereby changing the output to the "0" state, turning off the transistor Q4 and turning on the transistor Q3. Current now flows through the stator coil 42*a* energizing the stator pole face 41*a* as a "south" pole and the pole face 41*b* as a "north" pole. The attraction-repulsion sequence continues in this configuration for another 180° of rotation, i.e. until the magnets 50*b* completely clear both Hall switches 70 and they return to their "1" states, whereupon the stator coil 42*b* is again energized. The sequence continues to maintain rotation.

When power to the motor is turned off, the

rotor will assume a de-energized position, such as sown in Figure 2. In the motor illustrated, four de-energized positions are possible: Two primary positions in which the rotor magnets are centered on the larger diameter stator pole surfaces, as in Figure 2, and two secondary positions with the rotor magnets centered at points intermediate the primary positions. It does not matter which rotor magnet is facing which stator pole face when stopped, since the Hall switches will be appropriately energized or de-energized upon reapplication of power to assure immediate starting in the proper direction of rotation.

From the foregoing, it will be evident that the present invention provides a simple, reliable and inexpensive D.C. brushless motor that avoids many of the shortcomings of the known devices. Although a two-pole embodiment has been described, the principles of the invention are equally applicable to other multiple pole configurations. Similarly, different configurations of the rotor magnets may be employed. For example, a single magnet segment may be used in place of each magnet pair *50a*, *50b*, or a continuous ring magnet with appropriately magnetized segments may be employed. Further, as noted hereinabove, the invention is applicable to the conventional interior rotor-exterior stator motor arrangement, as well as the inverted configuration described.

It will be appreciated that in the above described brushless D.C. motor, that by virtue of the use of the circuit employed to effect switching of the stator poles, the same circuit board and components may be used with motors requiring different D.C. potentials for operation. For example, identical circuit boards may be utilized in motors whose operating voltages range up to 56 volts. This results in substantial manufacturing savings and simplicity, allowing production of a variety of motors for different purposes with substantial economies over systems requiring separate circuit designs for each different motor.

Attention is drawn to our Application No. 81.301930.4. (Publication No. 0040484) from which this Application has been divided.

Claims

1. The combination of a brushless D.C. motor and a commutation circuit; the motor having at least one stator winding (42) and a permanent magnet rotor (20); the semiconductor commutation circuit means (60, 62) for switching current in the at least one winding (42) of the stator (30) in dependence on the angular position of the rotor and to change the angular position of the magnetic field of the stator; the rotor carrying at least one permanent magnet (50) having at least one pole proximate the stator, extending arcuately through a first angle and operative to impart rotary motion of the rotor upon commutated energization of the stator winding; the commutation circuit including switching means (Q_2—Q_4) having a first state for conducting current through the winding in one direction and a second state terminating conduction of current through the winding in that direction, and Hall effect sensing means (70) for detecting the angular position of the rotor to control commutation; characterized in that the Hall effect sensing means includes at least two Hall effect devices (70) for changing output states in response to a magnetic field and effectively arcuately spaced apart by a second angle (Θ), each Hall device being coupled in control relation with the same switching means to cause that switching means to assume one of its said states when the first of the Hall devices (70) is effectively proximate the rotor permanent magnet pole (50a), maintaining the switching means in said one of its said states when either or both Hall devices (70) are effectively proximate said magnet pole (50a) and returning the switching means to the other of its said states when the second Hall device (70) effectively leaves the influence of the magnet pole (50a), whereby the commutation arc of the permanent magnet is extended beyond the first angle of its arcuate spacing by the Hall devices.

2. The combination according to claim 1, further characterized in that the permanent magnets (50) of the rotor extend arcuately less than 180°, the Hall effect devices are at least two Hall switching means (70) changing output stages in for response to a magnetic field, said two Hall switching means are connected in "OR" configuration with the winding when either Hall switching means responds to the magnetic field on the one rotor magnet, whereby one winding is energized as one of the Hall switching means enters the magnetic field of the magnet and is de-energized when the other Hall switching means leaves the magnetic field of the one magnet, and whereby the effective arc of commutation of the rotor magnet is increased for commutation purposes.

3. The combination according to claim 2, further characterized in that the rotor comprises two of said rotor magnets (50a, 50b) defining, respectively, North and South poles facing the Hall switching means and arcuate unmagnetized areas between the two magnets, the two Hall switching means (70) are spaced apart arcuately substantially the arcuate spacing between the two magnets.

Patentansprüche

1. Kombination aus einem bürstenlosen Gleichstrommotor und einem Kommutationsschaltkreis, bei der der Motor mindestens eine Statorwicklung (42) und einen Permanentmagnetrotor (20) aufweist, die Halbleiterkommutationsschaltkreiseinrichtung (60, 62) zur Schaltung des Stroms in der mindestens einen Wicklung (42) des Stators (30) in Abhängigkeit von der Winkelstellung des rotors und zur Änderung der Winkelstellung des Magnetfeldes des Stators dient, der Rotor mindestens einen Permanentmagneten (50) trägt, von dem sich mindestens ein in der Nähe des Stators befindlicher Pol bogenförmig über einen ersten Winkel er-

streckt und durch den dem Rotor bei einer kommutierten Erregung der Statorwicklung eine Drehbewegung erteilbar ist, der Kommutationsschaltkreis eine Schaltereinrichtung (Q_2—Q_4), die einen ersten Zustand für eine Stromleitung durch die Wicklung in einer Richtung und einen die Stromleitung durch die Wicklung in dieser Richtung beendenden zweiten Zustand aufweist und eine Halleffektfühlereinrichtung (70) für eine Erfassung der Winkelstellung des Rotors zur Steuerung der Kommutation umfaßt, dadurch gekennzeichnet, daß die Halleffektfühlereinrichtung mindestens zwei ihre Ausgangszustände ansprechend auf ein Magnetfeld ändernde und effektiv bogenförmig um einen zweiten Winkel (θ) voneinander beabstandete Halleffekteinheiten (70) aufweist, deren jede in steuernder Beziehung mit derselben Schaltereinrichtung gekoppelt ist, um die Schaltereinrichtung zur Annahme eines ihrer Zustände zu veranlassen, wenn sich die erste der Halleinheiten (70) effektiv in der Nähe des Permanentmagnetpols (50a) des Rotors befindet, die Schaltereinrichtung in diesem einen ihrer Zustände zu halten, wenn sich eine der beiden oder beide Halleinheiten (70) effektiv in der Nähe des Magnetpols (50a) befinden und die Schaltereinrichtung in den anderen ihrer Zustände zurückzuführen, wenn die zweite Halleinheit (70) effektiv den Einfluß des Magnetpols (50a) verläßt, wobei der Kommutationswinkelbogen des Permanentmagneten durch die Halleinheiten über den ersten Winkel seiner Bogenerstreckung hinaus erweitert wird.

2. Kombination nach Anspruch 1, ferner dadurch gekennzeichnet, daß sich die Permanentmagnete (50) des Rotors im Bogen über weniger als 180° erstrecken, die Halleffekteinheiten mindestens zwei ihre Ausgangszustände ansprechend auf ein Magnetfeld ändernde Hallschaltereinrichtungen (70) sind, die zwei Hallschaltereinrichtungen in "ODER"-Konfiguration mit der Wicklung verbunden sind, wenn eine der beiden Hallschaltereinrichtungen auf das Magnetfeld des einen Rotormagneten anspricht, wobei eine Wicklung erregt wird, während eine der Hallschaltereinrichtungen in das Magnetfeld des Magneten eintritt und aberregt wird, wenn die andere Hallschaltereinrichtung das Magnetfeld des einen Magneten verläßt, und wobei der effektive Kommutationsbogenwinkel des Rotormagneten für Kommutationszwecke vergrößert wird.

3. Kombination nach Anspruch 2, ferner dadurch gekennzeichnet, daß der Rotor zwei der Rotormagnete (50a, 50b) aufweist, die jeweils den Hallschaltereinrichtungen gegenüberstehende Nord- und Südpole und bogenförmige unmagnetisierte Bereiche zwischen den beiden Magneten festlegen, wobei die zwei Hallschaltereinrichtungen (70) bogenmäßig im wesentlichen um den Bogenabstand zwischen den beiden Magneten voreinander beabstandet sind.

Revendications

1. Combinaison d'un moteur à courant continu sans balais et d'un circuit de commutation, le moteur ayant au moins un enroulement de stator (42) et un rotor (20) à aimants permanents; des moyens de circuit de commutation à semi-conducteurs (60, 62) pour commuter le courant dans le ou les enroulements (42) du stator (30) selon la position angulaire du rotor et pour changer la position angulaire du champ magnétique du stator; le rotor portant au moins un aimant permanent (50) ayant au moins un pôle à proximité du stator, s'étendant de façon arquée sur un premier angle et adapté pour impartir un mouvement de rotation au rotor lors d'excitations commutées de l'enroulement du stator; le circuit de commutation comportant des moyens de commutation (Q2-Q4) ayant un premier état pour conduire le courant à travers l'enroulement dans une direction en un second état achevant la conduction de courant à travers l'enroulement dans cette direction, et des moyens de détection à effet Hall (70) pour détecter la position angulaire du rotor pour commander la commutation; caractérisée en ce que les moyens de détection à effet Hall comportent au moins deux dispositifs à effet Hall pour changer les états de sortie en réponse à un champ magnétique, effectivement espacés de façon arquée d'un second angle θ, chaque dispositif Hall étant couplé en relation de commande avec lesdits moyens de commutation pour entraîner les moyens de commutation à prendre un desdits états quand le premier des dispositifs Hall (70) est effectivement à promimité du pôle (50a) d'aimant permanent du rotor, en maintenant les moyens de commutation dans ledit état quand l'un ou l'autre des dispositifs Hall (70) ou les deux sont effectivement à promimité dudit pôle d'aimant (50a), et en faisant retourner les moyens de commutation à leur autre état quand le second dispositif Hall (70) quitte effectivement l'influence du pôle magnétique (50a), par quoi l'arc de commutation de l'aimant permanent est étendu au-delà du premier angle de son espacement arqué par des dispositifs Hall.

2. Combinaison selon la revendication 1, caractérisée de plus en ce que les aimants permanents (50) du rotor s'étendent de façon arquée sur moins de 180°, les dispositifs à effet Hall sont au moins deux moyens de commutation Hall (70) pour changer les états de sortie en réponse à un champ magnétique, lesdits moyens de commutation Hall sont reliés en configuration "OU" avec l'enroulement quand l'un ou l'autre des moyens de commutation Hall répond au champ magnétique d'un aimant du rotor, par quoi un enroulement est excité alors qu'un des moyens de commutation Hall entre dans le champ magnétique de l'aimant et est désexcité quand l'autre moyen de commutation Hall quitte le champ magnétique dudit aimant, et par quoi l'arc effectif de commutation de l'aimant du rotor est augmenté dans des buts de commutation.

3. Combinaison selon la revendication 2, caractérisé de plus en ce que le rotor comprend deux desdits aimants de rotor (50a, 50b) définissant, respectivement, des pôles nord et sud fai-

sant face aux moyens de commutation Hall et des zones arquées non magnétisées entre les deux aimants, et les deux moyens de commutation Hall (70) sont espacés de façon arquée de sensiblement l'espacement arqué entre les deux aimants.

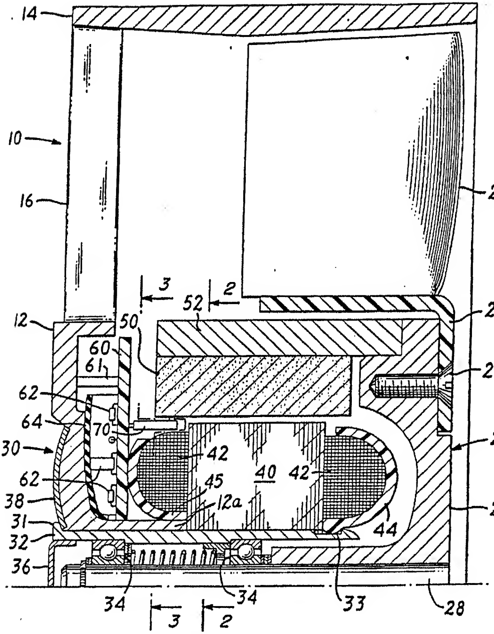
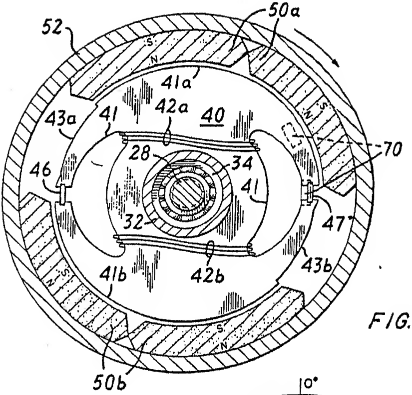
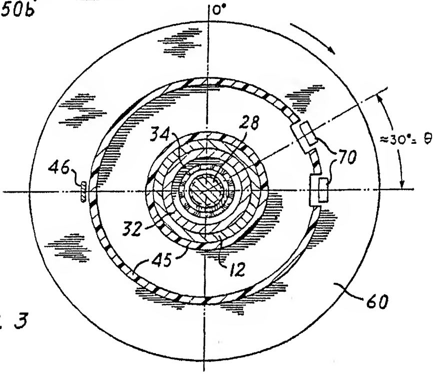

14
10
16
26
3
2
52
24
12
50
60
61
25
62
64
70
20
30
42
40
42
45
62
12a
38
22
31
44
32
36
34
34
33
28
34
3
2

FIG. 1



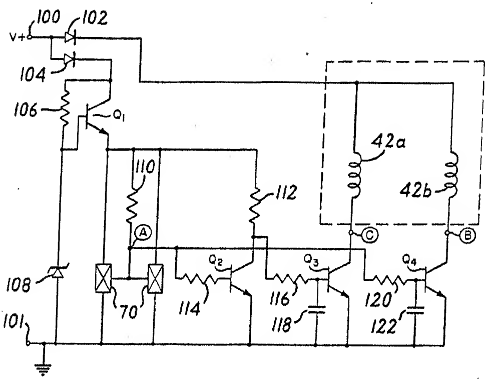
50a
52
41a
43a
41
42a
40
70
28
34
46
41
32
47
43b
41b
42b
50b

FIG. 2



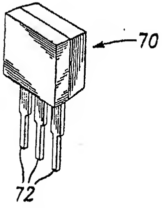
0°
28
34
≈30°= θ
70
46
32
45
12
60

FIG. 3



100
102
V+
104
106
Q1
110
112
42a
42b
A
C
B
Q2
Q3
Q4
108
70
114
116
120
118
122
101

FIG. 5



70
72

FIG. 4

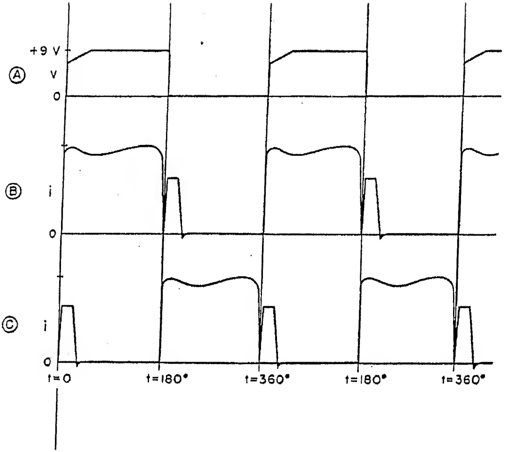


FIG. 6